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Summary

Heterodyne optical feedback on class-B solid state laser is applied for characterizing dielectric-loaded surface plasmon-polariton waveguides (DLSPPW) at telecom wavelength. Near-field optical images recorded on a series of DLSPPWs are compared to numerical models (mode-solver and finite-difference time-domain).

Introduction

Compared to other surface plasmon-polariton (SPP) waveguides, DLSPPWs are characterized by a good compromise between efficient light squeezing on sub-wavelength structures and reasonably long propagation range [1]. DLSPPWs can be easily fabricated using e-beam or photolithography. Moreover the dielectric ridge on the top of the metal could also be structured to implement passive or active functionalities [2]. Therefore, DLSPPW are very promising components for high-density optical circuits or interconnects between integrated circuits and optical links. Improvements on DLSPPWs are still underway to further increase the propagation length in order to obtain very long-range DLSPPWs with propagation length exceeding few hundred microns [3].

Experimental set-up and results

Polymer layer (resin SAL 601 negative resist; thickness h_{stripe}=600nm; refractive index n=1.68 @ 633nm) was spin-coated on 50-nm-thick gold film evaporated on a silica substrate. The polymer was micro-structured by e-beam lithography to pattern a series of rectangular micro-stripes with widths varying between w_{stripe}=500nm up to 4µm. A funnel, located at the beginning of each stripe waveguide, was added for efficient light coupling thanks to adiabatic effective index matching (figure 1a).

(a) (b)

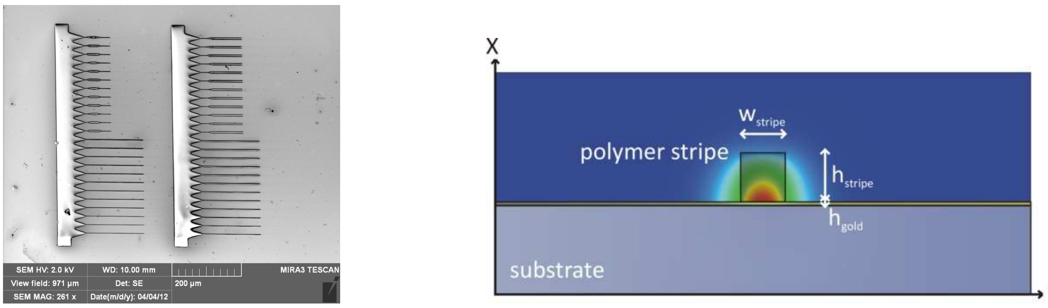

Fig 1. (a) SEM image of a DLSPP series fabricated by e-beam lithography; (b) Cross-sectional view of the DLSPPW structure and simulated transverse magnetic field distribution with h_{gold}=50nm, h_{stripe}=600nm and w_{stripe}=500nm.

The gold thickness h_{gold} as well as the height h_{stripe} and width w_{stripe} of the dielectric stripes were carefully designed following a series of numerical models based on mode solver and finite-difference time-domain (FDTD) simulations. For stripe width below 700nm, DLSPPW becomes single-transverse mode with quasi-TM plasmonic mode bounded to the gold/polymer interface (figure 1 b).
A scanning near-field optical microscope (SNOM) was used to characterize light propagation at λ=1.55µm along the DLSPPWs. The coherent detection is based on heterodyne optical feedback on DFB erbium-doped fiber laser. Laser optical feedback interferometry is extremely promising for near-field optical imaging because it allows quantum noise limited optical detection when the beating note resulting from the heterodyne feedback is adjusted close to the relaxation oscillations of the class-B laser [4], [5]. Uncoated sharpened fiber tip is raster scanned few nanometers above the DLSPPW for photon scanning tunneling microscopy. The distance between the top of the DLSPPW structure and the fiber tip is carefully controlled thanks to shear force monitoring. Example of topography and evanescent near-field optical distribution recorded simultaneously on a DLSPPW is illustrated on figure 2. The propagation length is measured equal to L_{SPP}=75.5µm in this configuration with a pattern characteristic of multimodal guiding.

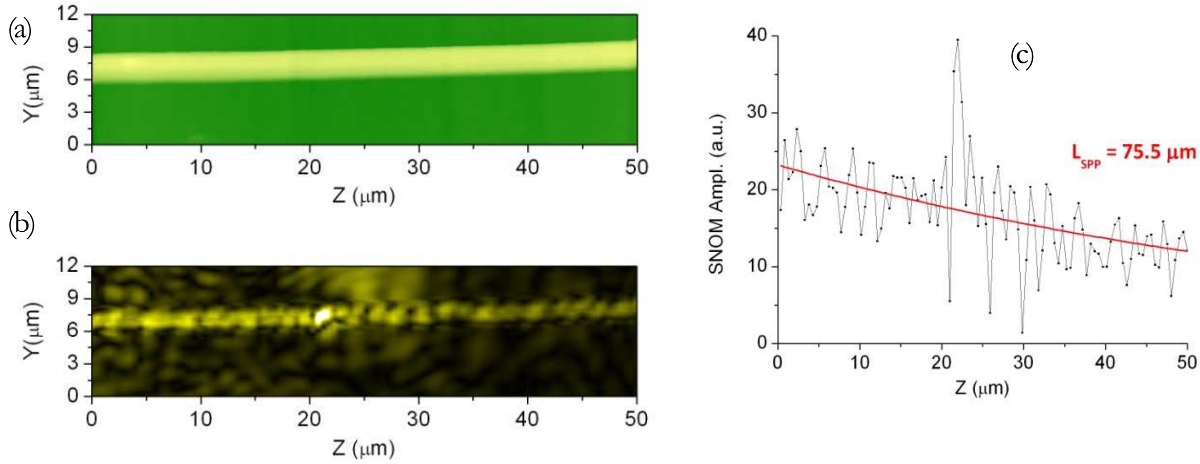

Fig 2. (a) Topography and (b) Optical near-field image on DLSPPW; (c) Propagation length L_{SPP}.

Conclusion

Investigations on other DLSPPW structures like splitters, coupling effect between adjacent waveguides or Mach-Zehnder interferometers (see figure 1 a) are underway and should be available at the time of the conference. Moreover, numerical models have also shown that adding a dielectric buffer layer of SAL 601 resin between the gold stripe and the substrate should further increase the propagation length L_{SPP}>500µm. It will be the next step in fabrication processes and SNOM characterization.

References

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